Fermi pockets in underdoped cuprate superconductors

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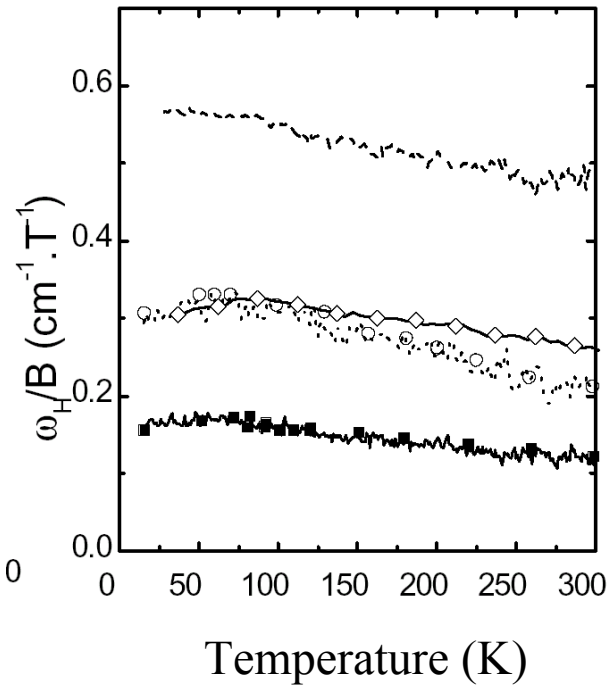
The nature of the pseudogap in underdoped cuprates is one of the most important questions in high temperature superconductivity. From Hall measurements at infrared frequencies we have obtained new evidence for a partial gapping of the Fermi surface as the carrier density is reduced from optimal doping. Gapping leads to a break up of the Fermi surface into smaller pieces with larger Hall frequencies and lower plasma frequencies as observed in the experiments. This gapping is a signature of density waves. Therefore, these results indicate that the superconducting state and a density wave state compete for the ground state in the cuprates and that the density wave state prevails at low carrier concentrations.



Temperature dependence of the Hall frequency for samples with different hole doping. The Hall frequency increases for underdoped $YBa_2Cu_3O_{7-\delta}$.

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High temperature superconductivity is one of the most important materials effects discovered in recent years. Understanding the phenomena is a key challenge in materials science. As chemical dopants are added to the insulating parent compounds they undergo an insulator to metal transition at a critical doping. Superconductivity occurs near the critical doping and become optimized at a somewhat higher doping level. Understanding the unusual properties of the underdoped state below the optimal doping is thought to hold the key to the understanding of the superconductivity. These new magneto-optical measurements give evidence that this state is a density wave state in which the charge can flow only in certain directions and that the restriction in the directions become greater as the doping is lowered until all charge is immobilized at the metal to insulator transition. Therefore, these results indicate that the superconducting state is destroyed by the density wave state as the carrier density is lowered.